VAST Real Time Tools and the Verification and Validation Simulation

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VAST-RT Background

- **VAST-Real Time capability is one of the deliverables of the Virtual Airspace Simulation Technologies (VAST) element**

- **Provide for evaluation of human performance and/or roles and responsibilities issues of new operational concepts**

- **Integrate models, simulation labs and facilities into a distributed network**

- **Leverage existing facilities and models**

- **Reconfigurable to meet different concept requirements**

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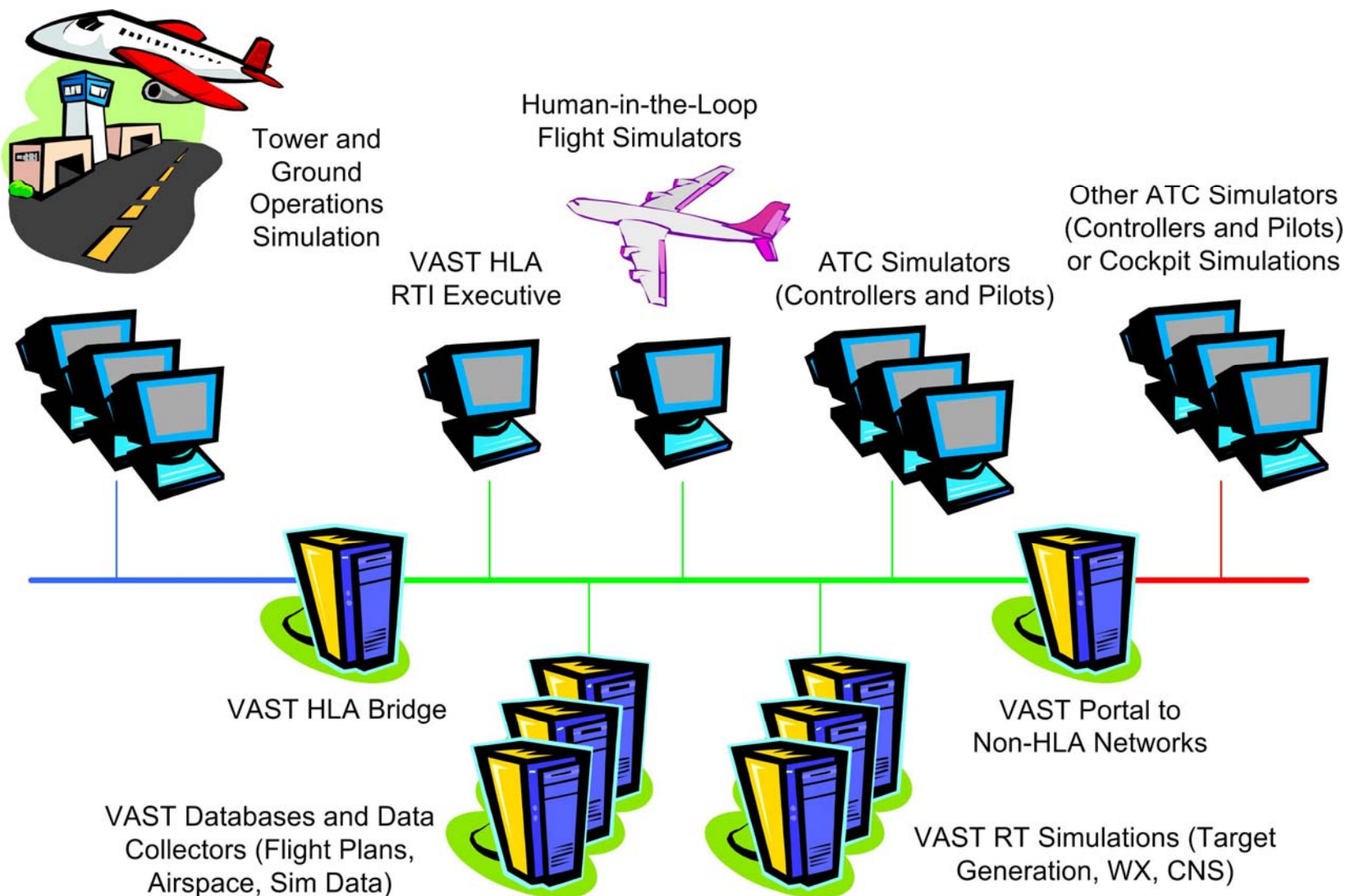
VAST-RT Delivered

- **Validated real time ATM simulation capability**

- **Enables distributed Human-in-the-Loop simulations for human factors studies**
  - Across multiple ATM domains
  - Research conducted in the best environment available
  - Study of roles and responsibilities

- **Also a platform to evaluate safety, efficiency, and capacity issues**

- **Supports investigations of existing and future operational concepts and decision support tools**

VAST Real-Time Innovations

- **Distributed simulation system**
  - Integrates labs and simulators of varying fidelity
  - Custom components supporting multi-domain ATM simulation, data collection, and research goals

- **Open architecture**
  - Allows rapid and cost effective integration of additional simulators, components, and decision support tools
  - Ability to redesign the national air space to model future concepts

- **Gate-to-Gate simulations**
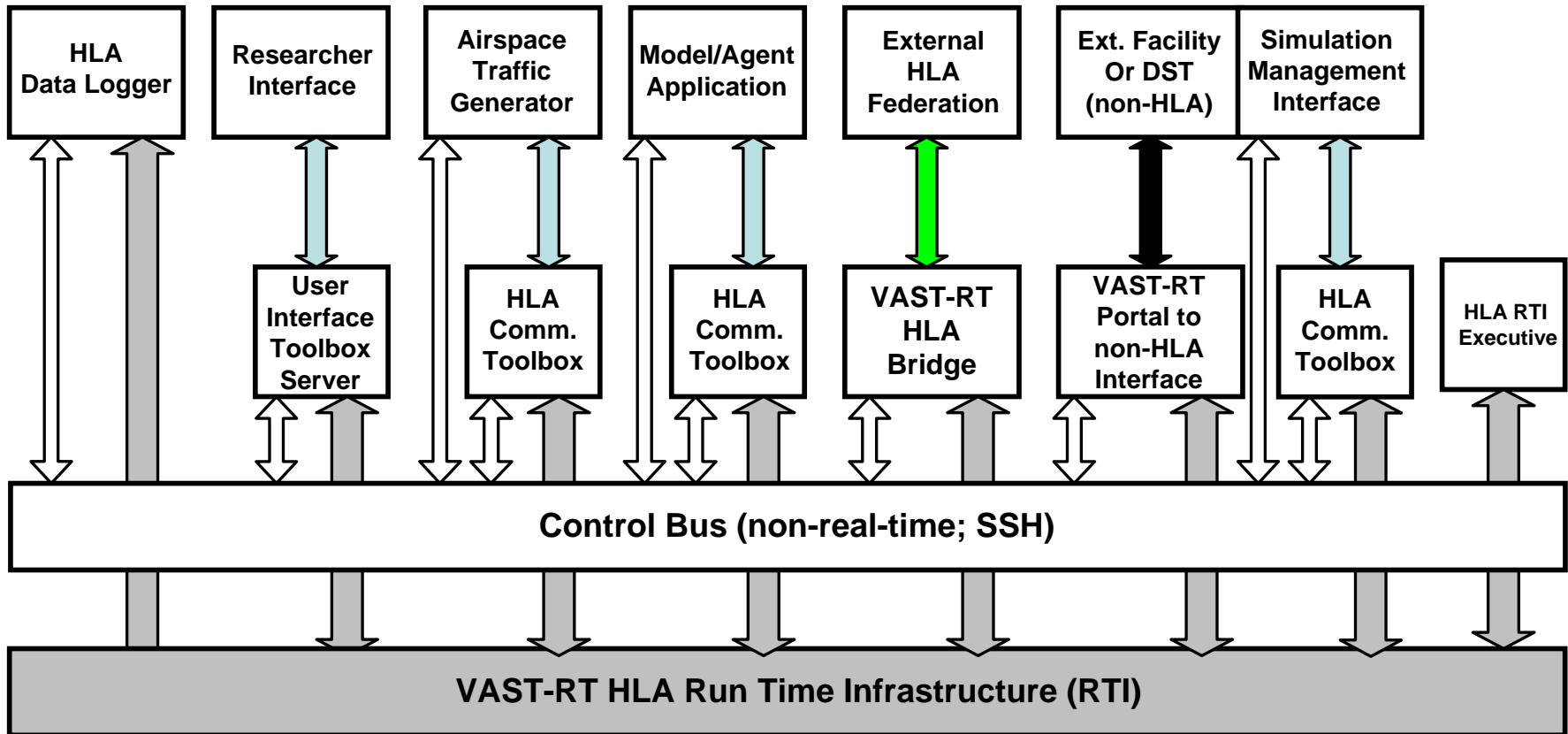 - Transfer of target ownership between simulation facilities

VAST-RT System Architecture

HLA Data Logger

Researcher Interface

Airspace Traffic Generator

Model/Agent Application

External HLA Federation

Ext. Facility Or DST (non-HLA)

Simulation Management Interface

User Interface Toolbox Server

HLA Comm. Toolbox

HLA Comm. Toolbox

VAST-RT HLA Bridge

VAST-RT Portal to non-HLA Interface

HLA Comm. Toolbox

HLA RTI Executive

Control Bus (non-real-time; SSH)

VAST-RT HLA Run Time Infrastructure (RTI)

Data Communications VAST-RT HLA RTI

Application Specific Interface

Non-VAST-RT HLA RTI

Non-HLA Customer Proprietary Interface

VAST-RT Simulation Management Interface

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VAST-RT Federation Object Model (FOM)

- **Customized for distributed ATM simulations**

- **Allows rapid modifications of simulation communications environment**

- **Implementation of both HLA attributes and interactions**

- **Synchronized process to update the FOM and Toolboxes**

Aircraft State
- identity
- position
- heading
- speed
- attitude
- articulation
- surveillance

Aircraft
- Tail Number

Ground Vehicle
- identity
- position
- heading
- speed

Flight Plan
- flight plan
- runway
- gate assignment
- center assignment
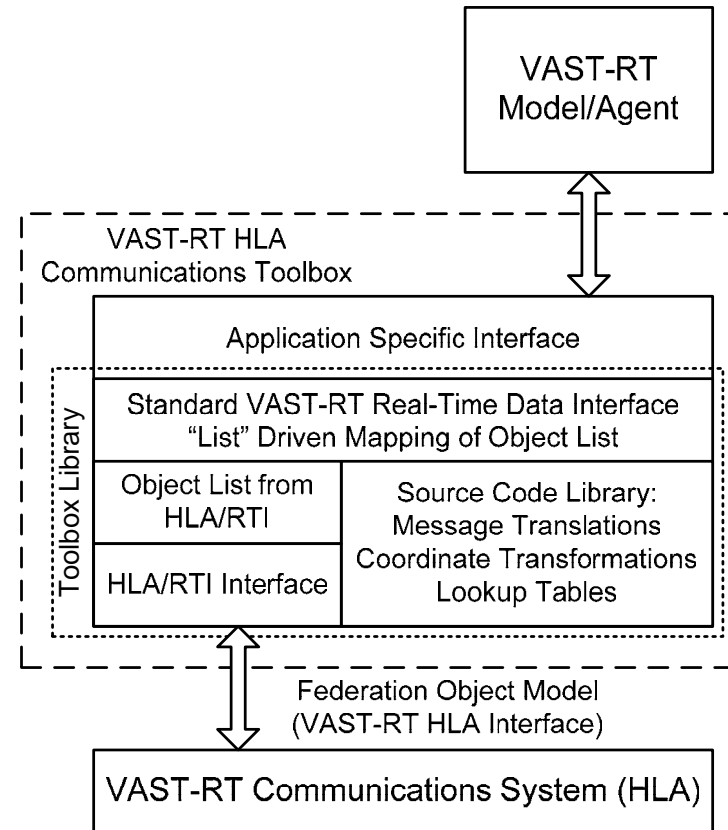- sector assignment
- meter fix
- taxi information

Simulation State
- state
- simulation time

Federate Status
- status

Interactions
+Ownership()
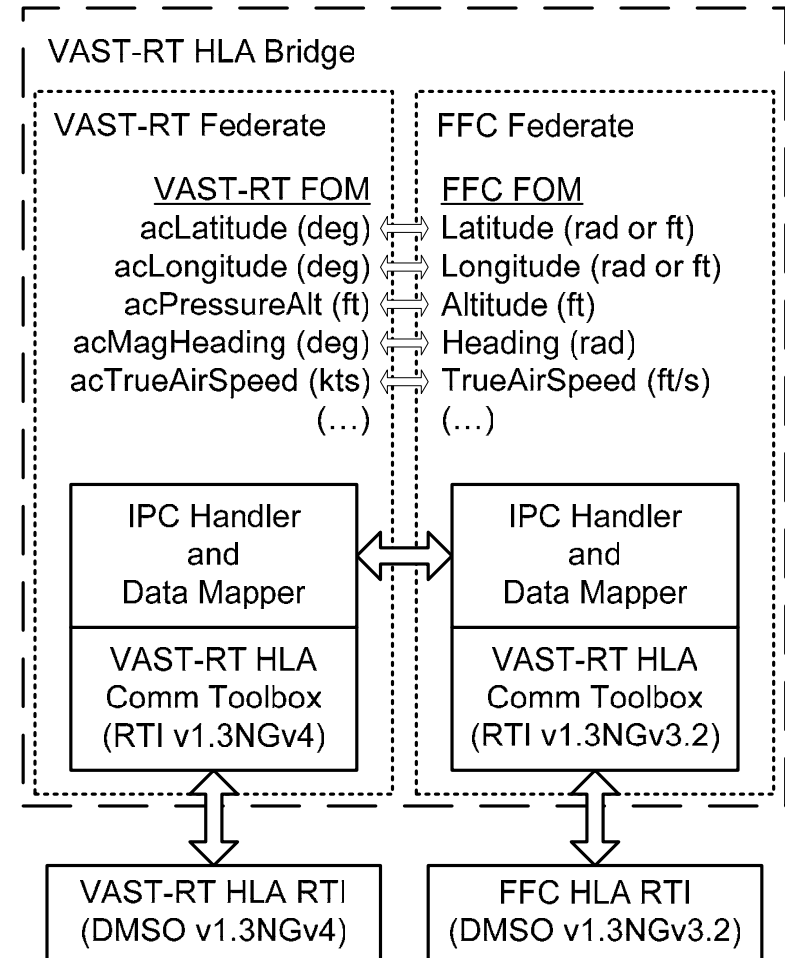+FP Amendment()
+Sim State Transition()

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VAST-RT HLA Communications Toolbox

- **Core component of the VAST-RT architecture**

- **Standardizes our interface to HLA RTI**

- **Leverages existing interfaces**

- **Reduces integration time and cost**

- **Reusable**

VAST-RT Model/Agent

VAST-RT HLA Communications Toolbox

Toolbox Library

Application Specific Interface

Standard VAST-RT Real-Time Data Interface "List" Driven Mapping of Object List

Object List from HLA/RTI

Source Code Library: Message Translations Coordinate Transformations Lookup Tables

HLA/RTI Interface

Federation Object Model (VAST-RT HLA Interface)

VAST-RT Communications System (HLA)

Bridging HLA Federations

- **HLA federations can be incompatible due to:**
  - HLA RTI Versions
  - HLA Federation Object Models

- **Bridging reduces or eliminates the need to modify an existing HLA simulator interface**

- **Bridge implementation handles data conversion**
  - Attribute Mapping
  - Coordinate Transformations
  - Frame rate differences

VAST-RT HLA Bridge

VAST-RT Federate	FFC Federate
VAST-RT FOM	FFC FOM
acLatitude (deg) ⟺	Latitude (rad or ft)
acLongitude (deg) ⟺	Longitude (rad or ft)
acPressureAlt (ft) ⟺	Altitude (ft)
acMagHeading (deg) ⟺	Heading (rad)
acTrueAirSpeed (kts) ⟺	TrueAirSpeed (ft/s)
(…)	(…)

IPC Handler and Data Mapper ⟺ IPC Handler and Data Mapper

VAST-RT HLA Comm Toolbox (RTI v1.3NGv4)

VAST-RT HLA Comm Toolbox (RTI v1.3NGv3.2)

VAST-RT HLA RTI (DMSO v1.3NGv4)

FFC HLA RTI (DMSO v1.3NGv3.2)

VAST-RT Bridges and Portals

- **A Bridge allows two different HLA architectures to interact**

- **A Portal connects a non-HLA based architecture to the VAST-RT HLA implementation**
  - Different methods for data marshalling and messaging
  - Synchronous vs. asynchronous operation

- **Bridges currently supporting:**
  - FutureFlight Central - a high fidelity tower simulator

- **Portals currently supporting:**
  - AOL (Airspace Opertations Laboratory) - a high fidelity TRACON simulator
  - GO-SAFE - a VAMS concept decision support tool

- **Source available**

Ownership Handoff Manager

- **Controls ownership of objects in the simulation**
  - Allows the researcher to use the most advantageous simulator for each part of a simulation
  - Centralizes the ownership logic which does not have to be programmed into each simulator and tool
    - External interfaces of simulators need to provide for remote creation and deletion of traffic

- **Automatically determines ownership based on target location and experiment rules and triggers transfer interaction**

- **Programmable for different research requirements**

- **Source available**

VAST-RT Air Traffic Generator (ATG)

- **Facility-independent target generator**
  - Used where participants are not needed in the loop
  - Saves money when running large distributed simulations

- **Supports airborne and ground operations**
  - Integrated into one simulator
  - Common fidelity
  - Gate-to-gate

- **Pseudo-pilot interfaces for optimized for each domain**

- **Accepts data link commands**

- **Loop closing agent**

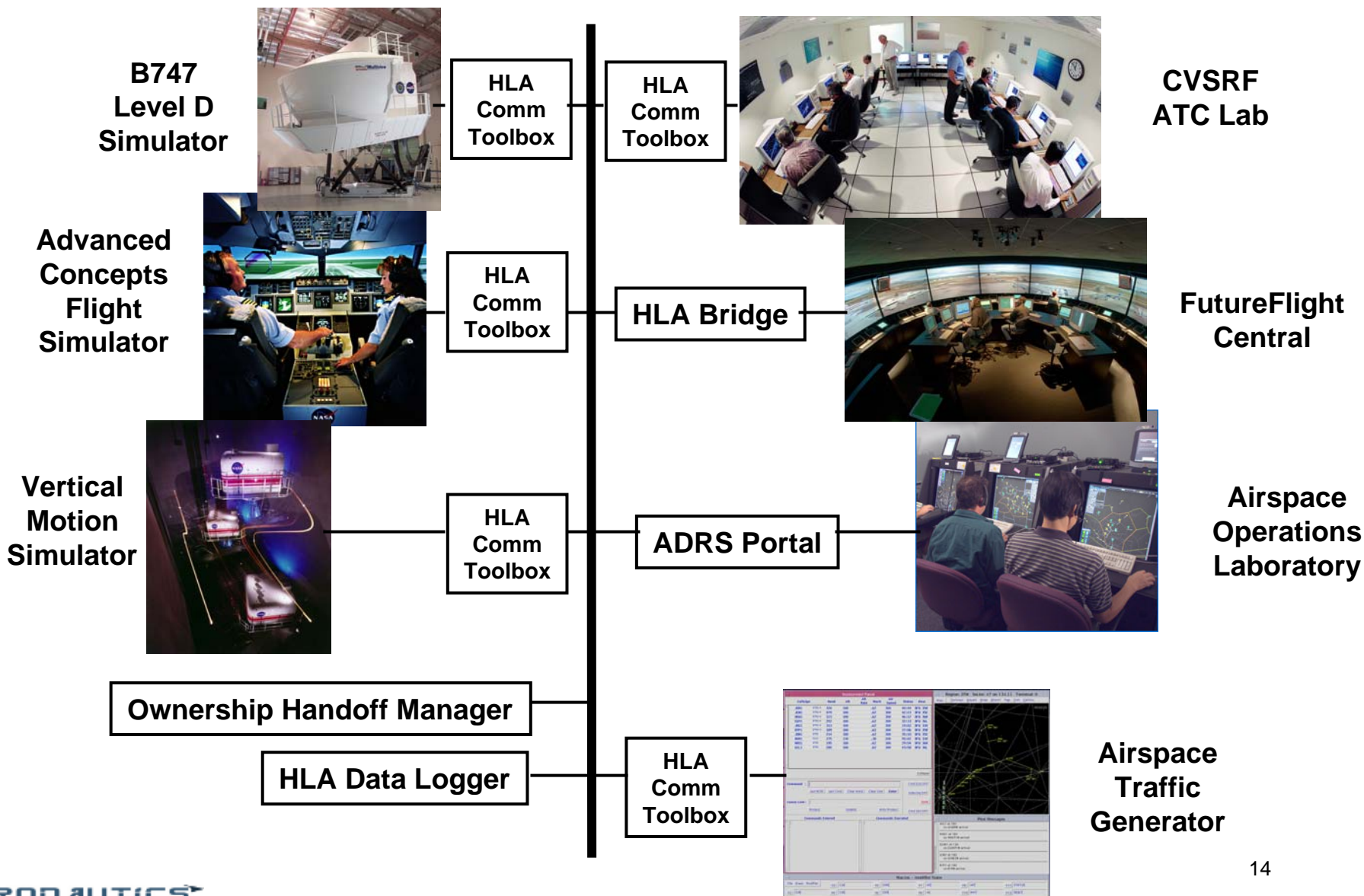- **Source available**

ATG Architecture
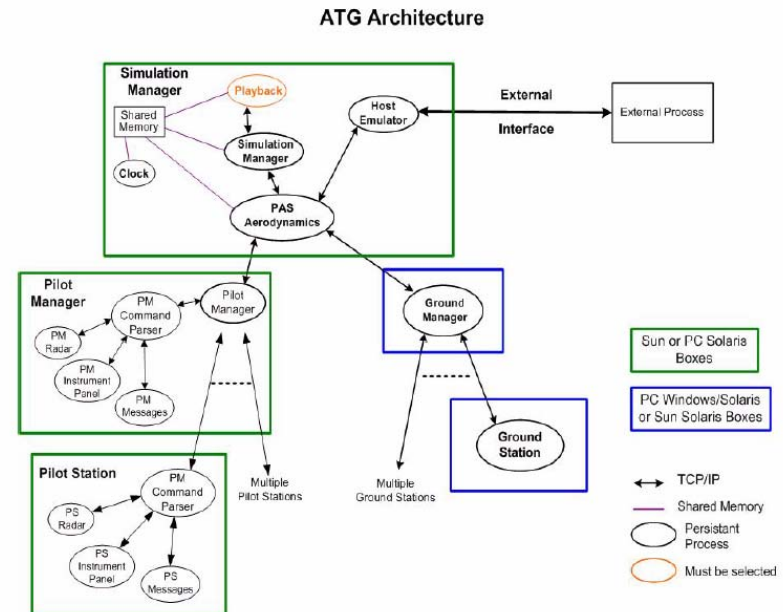
Additional Software Components

- **User Interface Toolbox (UIT) Server/Client**
  - Web enabled XML data server
  - Client application for remote observation of simulations

- **HLA Data Logger**
  - VAST-RT-developed distributed simulation data logger

- **Flight Data Processor**
  - Provides data needed by some simulators but not generated or stored in other simulators

- **Simulation Time Federate**
  - Distributes a simulation master clock

B747
Level D
Simulator

HLA Comm Toolbox

HLA Comm Toolbox

CVSRF
ATC Lab

Advanced
Concepts
Flight
Simulator

HLA Comm Toolbox

HLA Bridge

FutureFlight
Central

Vertical
Motion
Simulator

HLA Comm Toolbox

ADRS Portal

Airspace
Operations
Laboratory

Ownership Handoff Manager

HLA Data Logger

HLA Comm Toolbox

Airspace
Traffic
Generator

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Final Delivery

- **VAST-RT Capability 1.1**
  - Increased capacity in the Air Traffic Generator
  - Expansion of attribute and interaction set

- **VAMS Concept Evaluation**
  - Initial integration of the GO-SAFE DST

- **Other ATM Simulation Projects**
  - Shuttle Convoy (VMS and FFC)
  - Army (JAMUS UAV Simulation)
  - ACCESS5 (UAV – ATM Integration Simulation)
  - Dallas /Fort Worth Airport end around taxiway evaluation
  - FAA Tech Center

Concluding Remarks

- **VAST-RT successfully implemented an open, distributed simulation architecture**

- **Supports the rapid, reusable, and cost effective integration of simulators and components with varying levels of fidelity**

- **Extends the capability of existing high fidelity human factors simulators**

- **Provides the ability to conduct system-level studies to evaluate air traffic safety, efficiency, and capacity for new ATM concepts**
    - Human-in-the-Loop
    - Across Multiple ATM Domains

- **Can support existing and future airspace operational concepts and decision support tools**

- **Validated by SEA**

VAST Real-time FY04 Simulation Verification and Validation (V&V) Requirements

- **Purpose: To test VAST Real Time tools in FY04 using an AATT concept**

- **Approach**
  - Select a concept that has been tested in previous work
  - Prepare the real-time tools to test this concept using the current set of tools
  - Attempt to replicate the findings from previous work using the real-time toolbox to validate the toolbox development
  - Provide pathways to future tests in the real-time environment

- **System Evaluation and Assessment (SEA) is responsible for experimental requirements**

Lessons Learned

Current System Evaluation Methods: Air-Ground Integration Experiment

B747-400 Simulator at NASA Ames

Real-Time Link

FAA William J. Hughes Technical Center Lab

Data

Timing variables
Closest Point of Approach
Aircraft maneuvers
Workload data
Communication timing
Cockpit display data
Alerting logic data

Limitations:

• **Data for a limited airspace region (Two sectors in Memphis Center)**
• **Two years of development and preparation**
• **High cost for development and running of subjects**

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Requirements for the VAST Real Time V&V

- **Include at least two facilities**
- **Multiple airspace domains**
- **Test at least two parts of the triad (flight deck and ATC)**
- **Emphasize common architecture and data management and analysis**
- **Sequential testing prior to FY04 test**
- **Should be concerned with automation topics, with an emphasis upon human factors**
- **Should be closely related to some of the advanced concepts derived from the SLIC sub-element**

VAST Real Time V&V Approach

- **SEA element generated the research requirements**
  - Mapped research requirements to those of AATT Distributed Air-Ground Research

- **VAST-RT team conducted development efforts**
  - Several iterations to fine-tune the requirements

- **Several Interim Tests and reviews were held**
  - SEA participated in evaluations at test intervals

- **SEA and VAST prepared the verification/validation report of the VAST RT tools**

VAST Real-Time V&V Tools

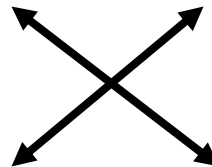Crew Vehicle Systems Research Facility

FutureFlight Central

Air Traffic Generator

Airspace Operations Lab 21

Scenarios for
VAST Real Time V&V

- **Airspace between Dallas-Fort Worth airport (DFW) and Chicago airport (ORD)**
  - AOL = DFW enroute and terminal airspace (only north half was actively controlled)
  - Also simulated Kansas City (ZKC), Chicago (ZAU), and Houston (ZHU)
  - ATG = ZKC and ZAU
  - FFC = East side of DFW airport
  - ACFS = started in ZFW airspace and landed 17L or 17C at DFW airport
  - Five simulated aircraft flew to ORD

- **Approximately 100 aircraft in scenario**

Some Data Collected from VAST Real-time V&V

- **Focus of data collection was to determine that the data were valid and sufficient for future tests**

- **Aircraft performance data**
  - Altitude, speed, braking, etc.

- **Data related to flight deck tools**
  - FMC/CDU data, Mode Control Panel data

- **Surveillance data**

- **Video and audio recordings**

- **Data management and configuration were also conducted to insure the ability to conduct analyses**
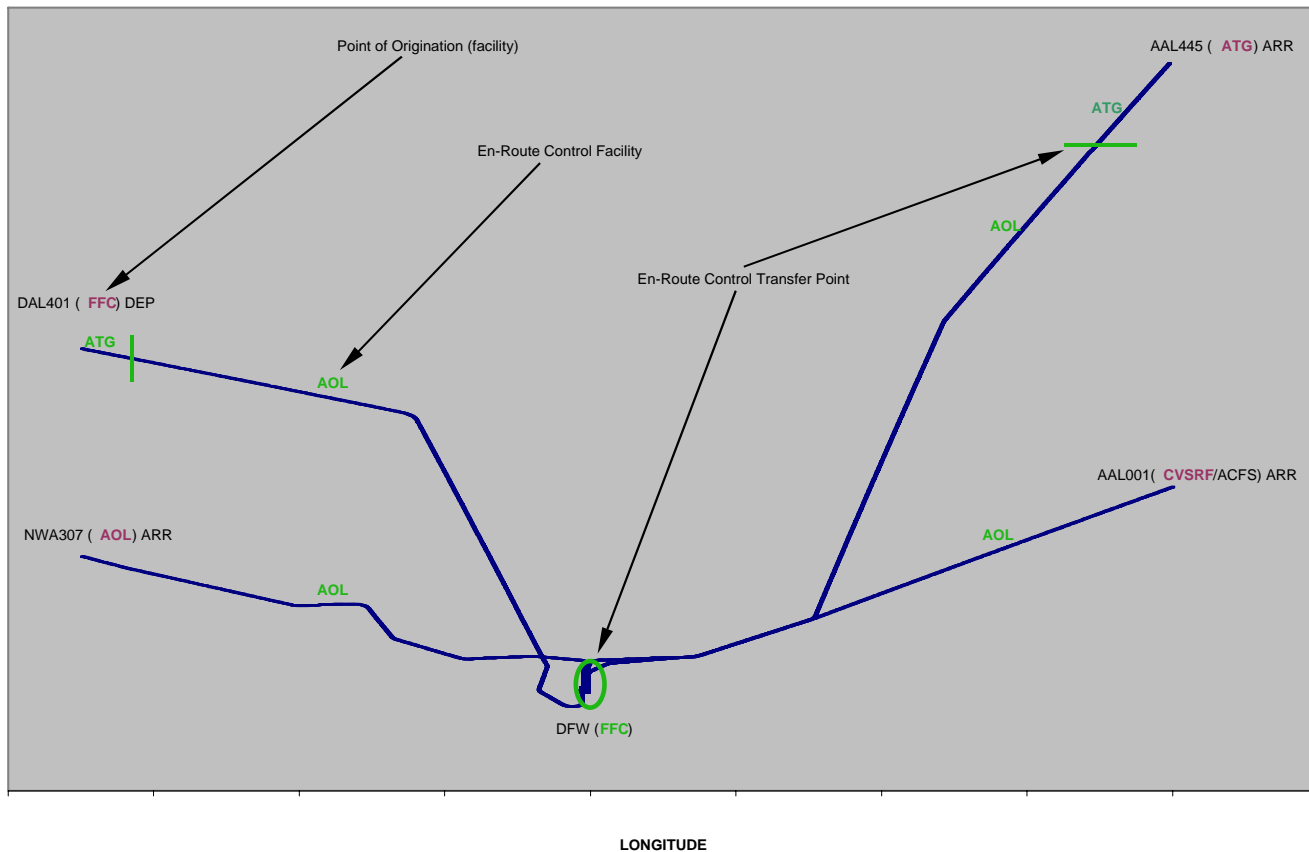
Aircraft Taxi Duration from Touchdown to Gate Arrival: V&V Run 5
(includes stops and movement times)
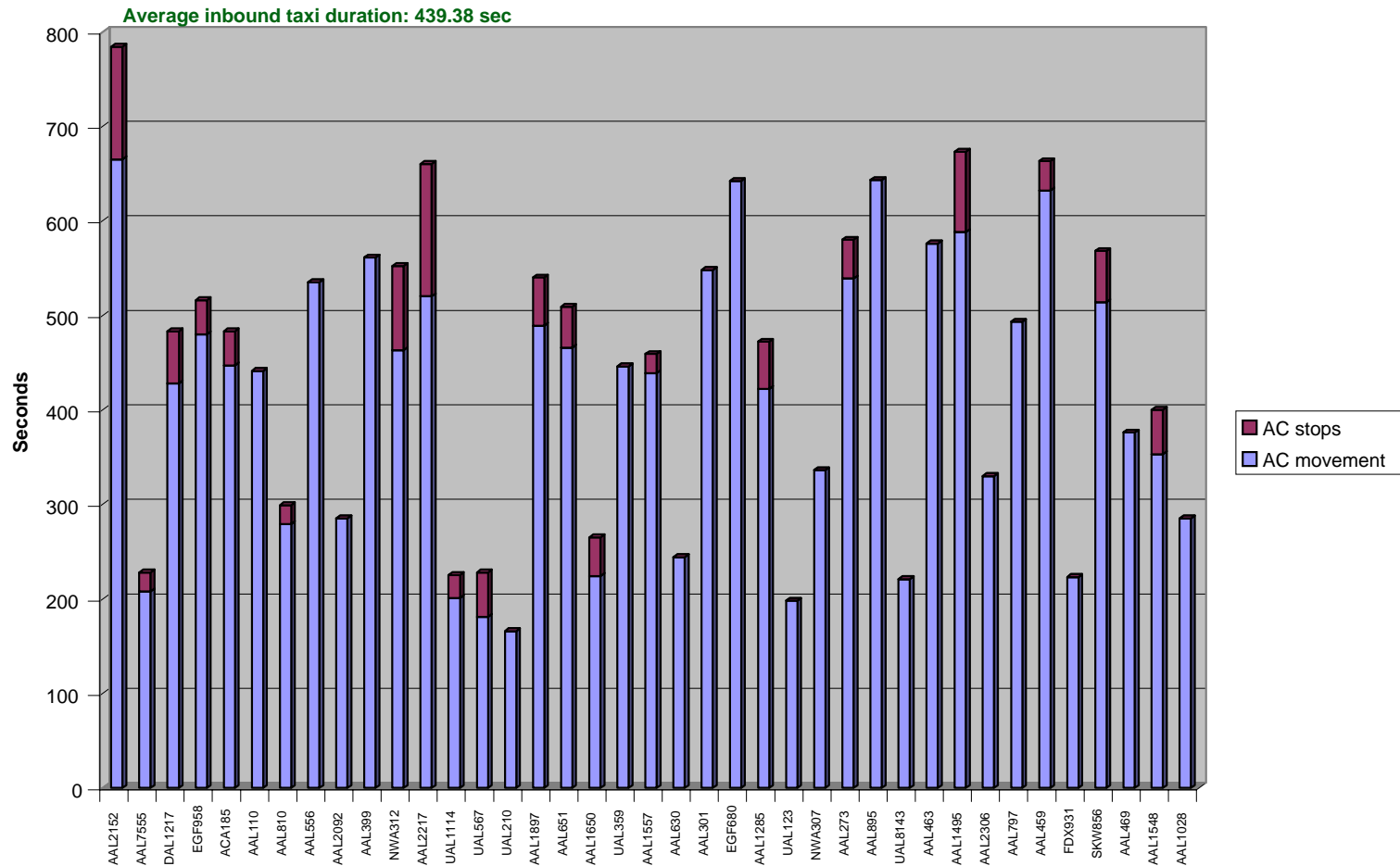
Sample Data from VAST Real Time V&V:Facility and Aircraft Ownership

Two-Dimensional Flight Paths of Selected Arrival and Departure Aircraft (V&V run4)

Point of Origination (facility)

En-Route Control Facility

En-Route Control Transfer Point

AAL445 (**ATG**) ARR

ATG

AOL

DAL401 (**FFC**) DEP

ATG

AOL

AAL001(**CVSRF**/ACFS) ARR

NWA307 (**AOL**) ARR

AOL

AOL

DFW (**FFC**)

LONGITUDE

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VAST Real Time V&V Challenges

- **Data management from the VAST V&V Simulation**

  - Multiple facilities with different data collection protocols and facility dependent formatting

  - Time synchronization among the different data sets was more challenging than originally determined (simulator + video + communications data)

  - Future work will need more detailed data collection variables to accommodate individual tools, concepts, and specific human performance parameters

VAST Real Time V&V Accomplishments

- **Multiple facilities were linked, integrated, and tested**

- **The data from previous simulations were comparable, and the V&V frequently exceeded previous data collection capabilities**

- **The VAST-RT facility is able to provide important human performance data for future concept assessment**

- **The VAST-RT development team did an outstanding job, and exceeded the simulation integration requirements for this verification task**